PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY

1999 No.3

Marine Corps Amphibious Triad Rollout

The first prototype of the advanced amphibious assault vehicle (AAAV) was recently unveiled at Quantico Marine Corps Base, Virginia. The ceremony presented the three elements of the amphibious triad—the AAAV, the landing craft air cushion (LCAC), and the MV-22 Osprey—all together for the first time.

Brigadier General James Feigley, USMC, Commander, Marine Corps Systems Command, pauses for photo with ARL Penn State's iMAST Director, Henry Watson. BGen Feigley previously served as the Direct Reporting Program Manager (DRPM) for the AAAV prior to assuming his current position at Quantico, Virginia.

The AAAV is a self-deploying, high-water-speed, fully tracked, NBC-protected, armored amphibious personnel carrier that will provide immediate high-speed maneuver of Marine infantry units as they emerge from attack positions aboard ships located over the horizon—25 miles and beyond. The AAAV represents an integration of existing combat-proven and emerging state-of-the-art technologies. Extensive cost/performance/requirements trade studies have resulted in a design providing fully optimized performance capabilities while achieving aggressive system-cost goals.

The AAAV Program Office is considered a pioneer of joint government and industry teaming. It was one of the first major programs to occupy a shared facility with its prime contractor, General Dynamics Land Systems. The result of this teaming has produced a seamless and synergistic advanced technology weapon system capable of maximizing the combat effectiveness of the AAAV while maintaining affordable system total ownership costs for the Marine Corps. iMAST is working with the program office to produce advanced manufacturing processes that will reduce weight in the road wheel wear rings of the track system. Advanced manufacturing of drive system components through the ausform finishing process is also being evaluated.

Two more first-generation AAAV prototypes will be built. Information gathered from these tests will be incorporated into the design of the second-generation prototypes, currently scheduled for delivery in fiscal year 2002. Initial operational capability to the Fleet Marine Force is anticipated during fiscal year 2005.

FOCUS ON HIGH ENERGY PROCESSING

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **iMAST Quarterly, 1999 Number 3**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Penn State University,Applied Research Laboratory,Institute for Manufacturing and Sustainment Technologies,State College,PA,16804**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

PENNSTATE
iMAST
Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

DIRECTOR
Henry E. Watson
(814) 865-6345 hew2@psu.edu

THRUST LEADER
Mechanical Drive Transmission Technologies
Alphonse J. Lemanski
(814) 863-4481 ajl3@psu.edu

THRUST LEADER
Materials Science Technologies
Maurice F. Amateau, Ph.D.
(814) 863-4481 mfa1@psu.edu

THRUST LEADER
High-Energy Processing Technologies
J. Thomas Schriempf, Ph.D.
(814) 863-9912 jts6@psu.edu

THRUST LEADER
Navy/Marine Corps Repair Technologies
Lewis C. Watt
(814) 863-3880
lcw2@psu.edu

iMAST ADMINISTRATOR and EDITOR
Gregory J. Johnson
(814) 865-8207 gjj1@psu.edu

STAFF ASSISTANT
Carol Ott
(814) 863-3207 (814) 863-1183 FAX
cvo1@psu.edu

WORLD WIDE WEB
www.arl.psu.edu/core/imast/imast.html

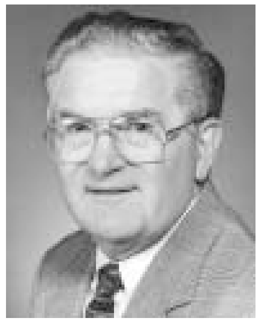
NAVY PROGRAM MANAGER
Ted Hicks
(215) 697-9528 hickst@onr.navy.mil

IN THIS QUARTERLY

DIRECTOR'S CORNER

New ManTech Thrust

I would like to use this issue of the iMAST newsletter to introduce you to a new electro-optics ManTech thrust at ARL. This program's genesis occured in 1998 when



ARL formed an alliance of 30 organizations from industry, academia, and government. The primary purpose of the Electro-Optics Alliance (EOA) was to develop a proposal to manage the Navy's electro-optics manufacturing technology development efforts in response to an Office of Naval Research (ONR) Broad Agency Announcement. This proposal was selected for funding by ONR and a cooperative agreement between ONR and ARL was signed February 26, 1999. The cooperative agreement is for a period of five years. Under this agreement, ARL has responsibility for the Electro-Optics Center's administration, technical program management and technology implementation and training. Alliance members will be selected and funded by the Electro-Optics Center (EOC) to help solve electro-optics problems for the Navy.

The EOC headquarters are located in Kittanning, Pennsylvania, in temporary facilities. Permanent facilities housing offices, laboratories and classrooms will be available for occupancy by the end of the year. A technology demonstration facility will be provided to transfer technology to industry.

The technical program is advancing at a rapid pace. By the end of 1999, at least seven technical programs will be under contract to EOA members. These programs result from manufacturing or performance issues identified by the Systems Commands and provided to ONR.

A survey is currently being conducted to determine the training needs of industry so that training programs can be identified or created as required. If you need more information about the EOC, please contact me.

Our feature article in this quarterly is by Eric Whitney of the High Energy Processing department. Eric is one of our experts in the field of laser cladding, which is an ongoing flagship program effort here at ARL. I think you will appreciate Eric's tutorial on the subject. Please give him a call if you have any questions.

As this goes to press, we will be preparing for our annual participation at the Defense Manufacturing Conference in Miami, Florida. Check our calendar of events for dates. And please plan to drop by and visit our booth if you will be attending DMC-99. We look forward to seeing you.

Henry Watson

PENNSTATE
iMAST

MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES | MATERIALS SCIENCE TECHNOLOGIES | HIGH-ENERGY PROCESSING TECHNOLOGIES | NAVY/MARINE CORPS REPAIR TECHNOLOGIES

Focus on High Energy Processing

Laser Cladding 101

by Eric J. Whitney

Laser cladding is often used as a means to achieve alteration of surface properties of a component. Laser cladding is utilized for the manufacture of production components and for the repair and refurbishment of field returned components. Although the laser process applied to production and repair is similar, the implementation approach is different. This article briefly describes the laser cladding process and highlights different engineering aspects for production of original components and repair of parts that were in service.

Laser Cladding Process

All laser cladding processes have certain elements in common. Laser cladding processes have, obviously, a laser source and a means to deliver and focus the laser, as well as a filler metal delivery system and a means to translate the part or beam. In addition, provisions for inert gas shielding and process sensors are often employed to modify the process for particular applications. Figure 1 shows a schematic of a laser cladding machine utilizing a 14-kW CO_2 laser.[1] In this system the laser beam is focused and scanned in the X direction and the part translated in the Y direction, powder is deposited ahead of the laser beam, and no auxiliary gas is used.

Figure 2 shows a schematic of a laser cladding nozzle that has an integral inert gas shielding diffuser. The nozzle was designed to be used in conjunctions with a 3-kW Nd:YAG laser and features a clamping arrangement for standard optics, an enclosed beam tube to allow for axial gas flow and an integral shroud to surround the laser interaction

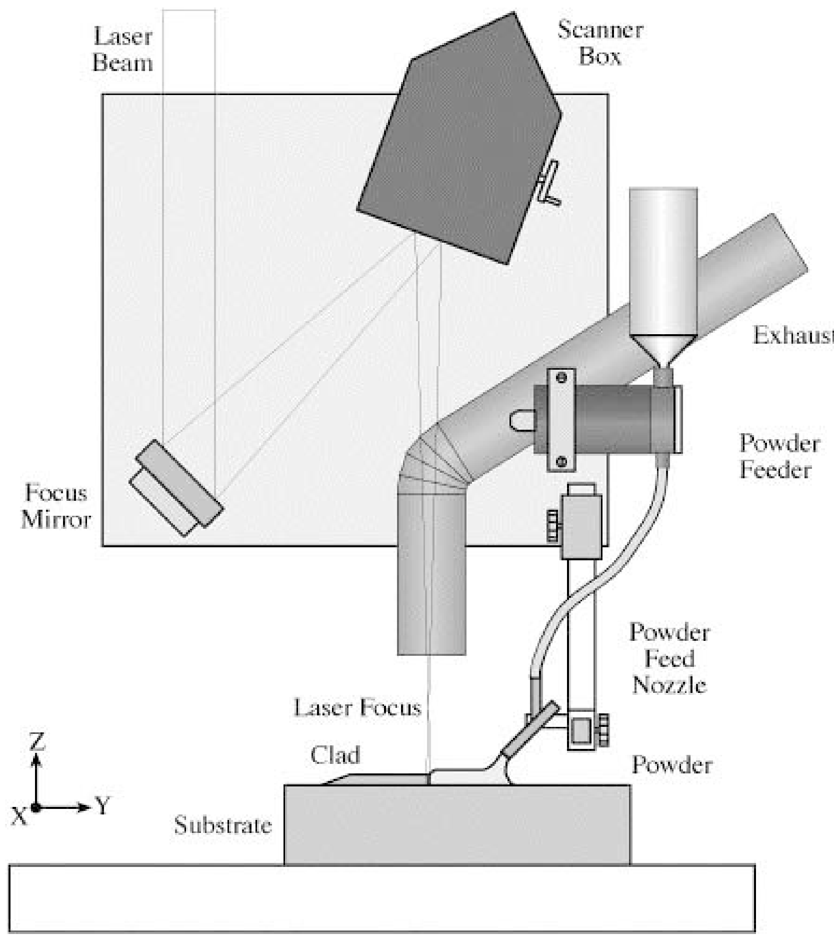


Figure 1. Laser cladding apparatus for high-power CO_2 laser.

PROFILE

Eric Whitney is a Ph.D. candidate at The Pennsylvania State University. He has served as a research assistant and associate in ARL's High Energy Processing department since 1991.

Mr. Whitney received an M.S. degree in Metal Science and Engineering from Penn State in 1995. He is a 1983 graduate of the University of Cincinnati with a B.S. degree in Metallurgical Engineering. Prior to joining ARL he was employed with GE-Aircraft Engines for twelve years.

Mr. Whitney's interests include the application of laser processing to ferrous and nonferrous materials, including laser free-form fabrication and laser cladding as a repair process. He is considered a national expert in the free-forming of titanium parts to near net-shape using powder metals and laser energy. Mr Whitney holds eight patents and is a registered professional engineer. He can be reached at (814) 865-3916 or by e-mail at: <ejw111@psu.edu>.

CONTINUED FROM PAGE 3

area with inert gas. The apparatus shown below has been used successfully to laser clad Ti-6Al-4 material without completely containing the part in a dry box.

The previous two examples are shown to illustrate the flexibility in designing a laser cladding system.

Laser Cladding Metallurgy

Laser cladding is a fusion welding process; i.e., the clad material and a portion of the substrate are molten and in contact with each other during processing. Therefore mixing occurs between the clad and substrate, forming a metallurgical bond, exactly analogous to conventional fusion welding processes. Figure 4 is a modification of a diagram of welding dissimilar metals first advanced by W.F. Savage.[2] There are four distinct regions: the composite region, the unmixed zone, the partially melted zone, and the true heat affect zone. The composite region is so called because its chemical composition is a weighted average of the amount of clad material and the amount of substrate melted and mixed into the clad region. In laser cladding the chemistry of the composite region is virtually indistinguishable from the composition of the clad powder; i.e., there is almost no mixing between the clad and the molten substrate. The unmixed region is the boundary condition in which the substrate becomes molten but does not mix into the composite region. The partially mixed zone is the area in which lower melting point phases melt while the remaining material remains solid. Cracking can originate in this area. The laser process minimized the partially melted zone as compared to conventional processing, thereby reducing the number of cracks associated with this region. The true heat affected zone is that part of the substrate that undergoes solid-state transformation and resulting microstructural changes. The true heat-affected zone is often ten times smaller in laser clads than in conventionally processed material.

Figure 4 shows an actual high-power laser clad. The clad material is nickel-aluminum-bronze, the substrate material is 4140, and laser power was 18 kW. Note the wide, uniform deposit and narrow heat-affected zone under the clad layer. In this case the heat affected zone depth is approximately one-half as deep as the clad is high.

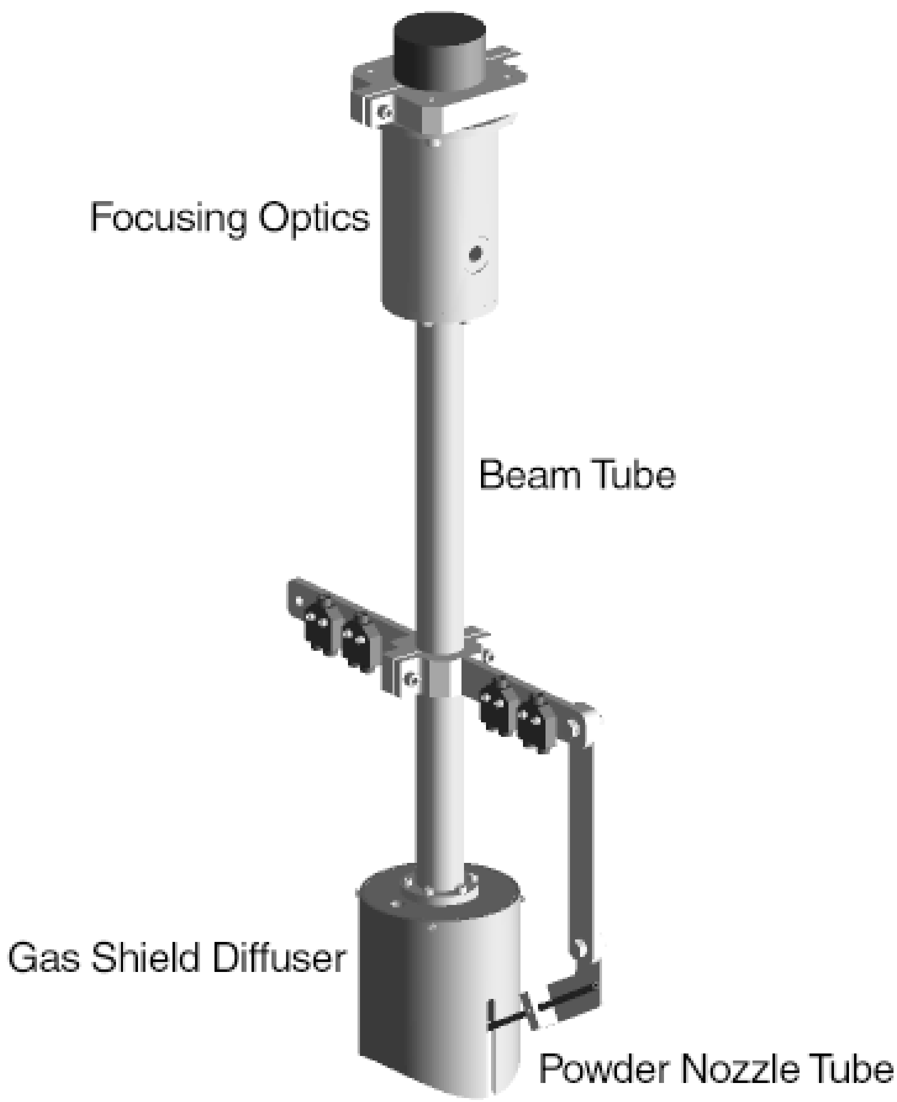


Figure 2. Cladding apparatus with integral gas diffuser for a 3 kW Nd:YAG laser.

Repair Design Approach to Implementing Laser Cladding as a Repair Process

Repair engineering is a discipline that is not formally acknowledged in the academic sense. However, it is becoming an increasingly important function within organizations charged with the upkeep of aging systems. Laser cladding is a valuable repair technique that can reduce costs and increase the number and type of components that can be repaired. As can be expected, the proper implementation of laser cladding requires knowledge of repair design methodologies and information specific to an application.

Repair Design Methodology

Repairs can be categorized into two broad classifications: repairs that do not affect the intended design life or load-bearing capability of the part and repairs that do. Clearly, it is important to assess the

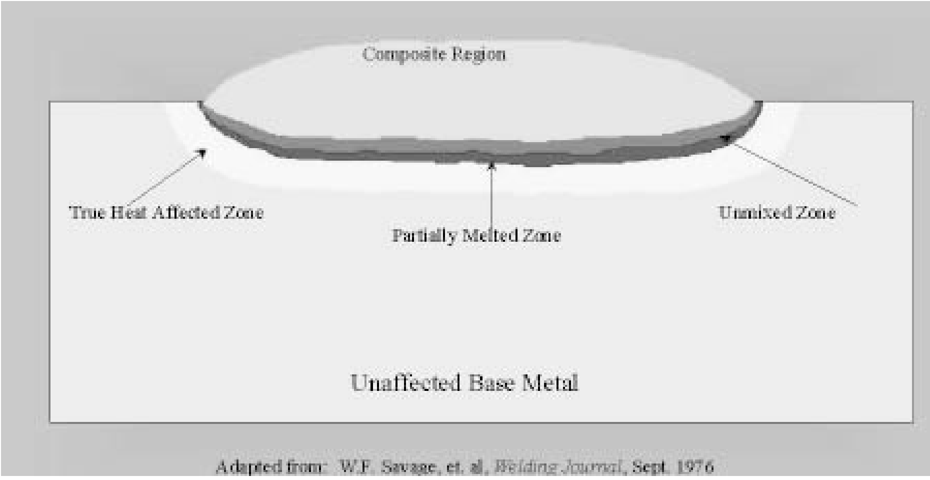


Figure 3. Schematic of a fusion cladding process.

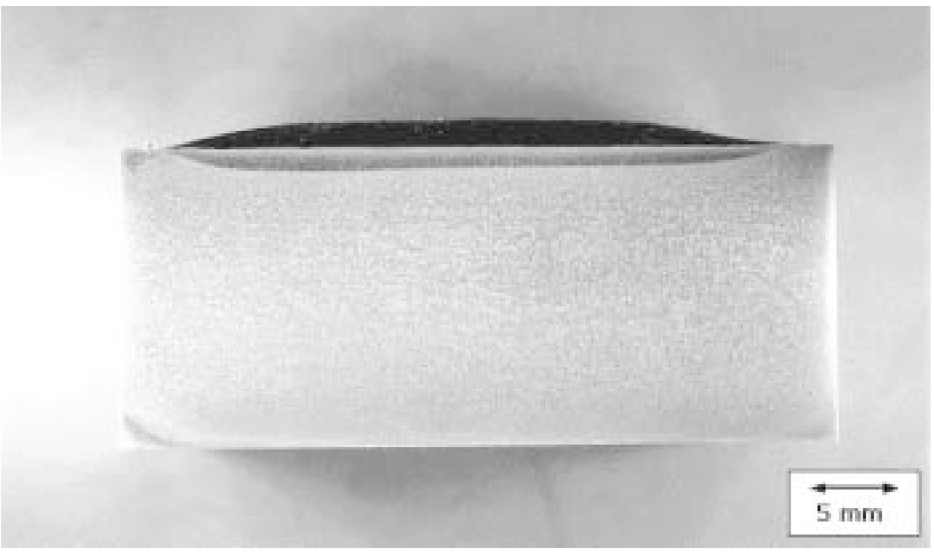


Figure 4. Nickel-aluminum-bronze on 4140 steel using a high-power CO_2 laser.

impact of repair on component performance. However, it is often difficult to obtain original design information for use in assessing a potential repair as a result repair, so engineers must be conservative when evaluating a new repair procedure or process.

When considering repair of a fatigue-limited component (nearly all rotating or reciprocating components in engines, motors, and pumps are fatigue-limited) it is advisable to determine the area of the part that is most likely the fatigue-limited region. For example, shafts often have splines that are subjected to the highest design stress and therefore are the fatigue-limiting location of the part. Such shafts commonly have bearing journals that are compressively loaded. In such a case, it is feasible to repair the journal area without changing the original design life of the component. Figure 5 shows a schematic of a shaft and repair. In the repair, laser cladding is permitted on the raised portion of the journal, and the depth of the heat-affected zone is limited so that it is entirely contained outside the region of the shaft transmitting torque. Such a repair design is ideal since it does not change the original design of the part and is inherently conservative.

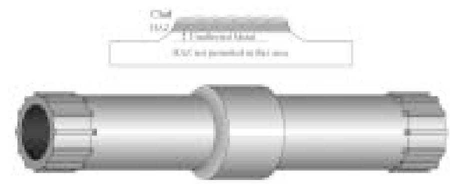


Figure 5. Example of shaft repair.

Summary

Laser cladding is a valuable technology available to the repair engineer. It can replace chrome electroplating in certain cases and may allow for the recovery of components currently considered to be scrap. Further, laser cladding forms a metallurgical bond between the clad and the substrate and, provided the design information is available, may allow the repair to be structural in nature. As with any repair processes, engineers must understand the technology so that it can be applied appropriately.

References

1. Whitney, E. and J. Kenneth Meinert, "Laser Surfacing through Laser Cladding," *The Fabricator*. 1997. p. 58-60.
2. Savage, W.F., E.F. Nippes, and T.W. Miller, *"Microsegregation in 70Cu-30Ni Weld Metal." Welding Journal* (Miami, Fla) 1976. 55(6): p. 165s-173s.

M&M Precision System's new M&M 3515 measuring machine, which is currently housed in iMAST's Drivetrain Technology Center's metrology laboratory. The machine is capable of precise profile, lead, and tooth-spacing measurements on high-performance gears.

Research engineer Terri Merdes (right) discusses on-going condition-based maintenance efforts at ARL with project engineer Rebecca Townsend and logistician Blondean Irving (center) from the TACOM Light Armored Vehicle office at Warren, Michigan.

LAV Anti-Air Variant.

New Acquisition for iMAST's Metrology Laboratory

M&M Precision Systems, Inc., of Dayton, Ohio, has provided ARL with a Model 3515 gear measurement system to support the current NIST ATP (Applied Technology Program) project: "Technologies for Gear Performance Prediction Utilizing Precision Optical Measurement." The research is being carried out by M&M Precision Systems Corporation and ARL's iMAST. The Applied Research Laboratory at Penn State is the principal subcontractor to M&M for the project. For more information about this program, contact Dr. William Mark at (814)-865-3922 or by e-mail at <wdm6@psu.edu>.

LAV Program Office Visits iMAST

Program leaders from the Light Armor Vehicle (LAV) program office at the U.S. Army Tank-automotive Armaments Command (TACOM) in Warren, Michigan, recently visited iMAST. Ms. Rebecca Townsend and Ms. Blondean Irving spent a full day reviewing ongoing ManTech projects. They also had time to visit many of the facilities. iMAST is currently addressing a crew compartment heater issue on the vehicle through a Navy ManTech repair technology project.

The LAV is an 8×8 wheeled light-armored combat, combat support, and combat service support variant vehicle. Primarily used by the Marine Corps for combat and combat support roles, the LAV incorporates a Detroit Diesel 6V53T diesel engine, which is capable of developing 275 horsepower, coupled to an Allison MT653, 6 speed (5 forward, 1 reverse) automatic transmission with driver-select gear ranges. Power is delivered through a single transfer case to four differentials. The four rear wheels drive the vehicle on a full-time basis, but eight-wheel drive is selectable.

The LAV has been designed and equipped with the capability, mobility, agility, and flexibility for operations in hot dry, hot humid, mild cold to cold climatic conditions. It can operate on highways, off-road, cross-country, on level and hilly unimproved roads, and within urban environments. Its low silhouette makes it a difficult target to detect and destroy.

LAV Profile:

- Length: 251.6 inches
- Width: 98.4 inches (turret facing forward)
- Weight: 24,100 pounds
- Range: 410 miles
- Crew: Driver, gunner, cmdr and 6 troops
- Unit Replacement Cost: $900,000
- Height: 106.0 inches
- Speed: 62 mph
- Combat Weight: 28,200 pounds
- Swim Speed: 6 mph
- USMC Inventory: 401

The all-terrain, all-weather vehicle has a night operation capability. It is air transportable via C-130, C-141, C-5, and the CH-53 E helicopter. LAV armament includes an M242 25mm chain gun and a M240 7.62mm machine gun mounted coaxial to the main gun. When combat loaded, there are 210 ready rounds and 420 stowed rounds of 25 mm ammunition as well as 400 ready rounds and 1200 stowed rounds of 7.62mm. There are 8 ready rounds and 8 stowed rounds of smoke grenades. A supplementary M240E1 7.62mm machine gun can be pintle-mounted at the commander's station in the turret. The LAV-25 is fully amphibious with a maximum of 3 minutes preparation.

For more information about ARL's LAV crew compartment heater project, contact Dennis Wess at (814) 865-7063, or by e-mail at <dbw105@psu.edu>. For more information about the LAV Program Office, visit their web site at <www.tacom.army.mil/LAV/>.

Lieutenant General McCorkle and Lewis Watt at DC/S Air's Pentagon office.

Marine Air Gets the Word

Lieutenant General Fred McCorkle, Deputy Chief of Staff for Aviation, Headquarters, U.S. Marine Corps, recently hosted members of iMAST at his Pentagon office. The general received a capabilities overview on aviation-related activities and technical capabilities ongoing at ARL Penn State as part of its Air Vehicle Technology Group effort. General McCorkle is tasked with keeping Marine Corps aviation on the leading edge technically, tactically, and doctrinally.

JSF Program Office Visits iMAST

iMAST's Lewis Watt (right) shows Colonel Currier examples of laser paint stripping efforts on a sample aircraft airframe structure.

Colonel Russ Currier, Director of Training and Supportability for the Navy and Marine Corps' Joint Strike Fighter program, recently visited ARL's iMAST center for a capabilities brief and facilities tour. The Joint Strike Fighter (JSF) Program, formerly the Joint Advanced Strike Technology (JAST) Program, is the focal point for the Department of Defense for defining affordable next-generation strike aircraft weapon systems for the Navy, Air Force, Marines, and our allies. The focus of the program is affordability—reducing the development cost, production cost, and cost of ownership of the JSF family of aircraft. The program is accomplishing this by facilitating the Services' development of fully validated, affordable operational requirements, and lowering risk by investing in and demonstrating key leveraging technologies and operational concepts prior to the start of Engineering and Manufacturing Development (E&MD) of the JSF in 2001.

iMAST is currently addressing a number of issues relative to the JSF including: high-temperature, high-strength spray-formed aluminum alloys for engine application; VSTOL drive system components; and repair, sustainment, and health monitoring issues.

Director, Expeditionary Warfare Technology Programs visits iMAST

Eric Whitney, ARL research assistant, shows LtCol Beal a ballistic-tested sample of laser free-formed titanium plating that has successfully survived "interrogation" by .50- and .30-caliber ammunition rounds.

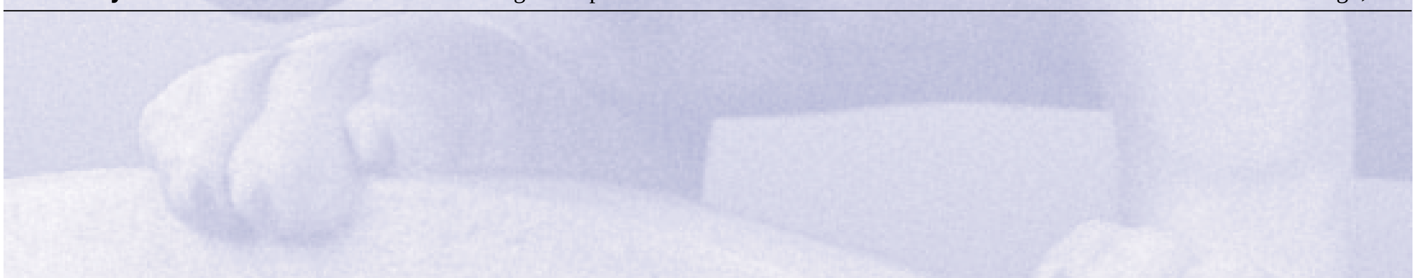
Lieutenant Colonel Dennis Beal, USMC recently visited iMAST as part of a technology review effort supporting development of the Marine Corps' next-generation tank. Colonel Beal is assigned to the Chief of Naval Operations (Code N911M). Responsible for determining the feasibility/viability of producing a revolutionary offensive combat system by year 2025, LtCol Beal has challenged research laboratories like ARL to "think outside of the box." ARL hopes to initially assist the program effort by providing conceptual design environment support. This system allows program directors the ability to evaluate the merits of new technologies and system configurations with regard to cost, performance, and technical risk. For more information about conceptual design environment support, contact Mr. Mike Yukas at (814) 863-7143 or by e-mail at <may106@psuy.edu>.

Penn State Northeast Showcase

iMAST recently particpated in Penn State's Commonwealth Campus Northeast Showcase at the Penn State Hazleton campus. The purpose of the showcase was to highlight to businesses the research opportunities available by teaming with Penn State. The synergy developed by bringing government, industry, and academia together as a team allows a focus of energy and effort towards meeting the challenges and opportunities that manufacturing technology will bring to the future. This principal mission of Navy ManTech is one that iMAST takes seriously.

CALENDAR OF EVENTS

21–22 Sep	NCEMT Modern Shipbuilding Technologies	Crystal City, VA
21–23 Sep	NDIA Combat Vehicles Conference	Fort Knox, KY
7–8 Oct	Electro-Optics Center Showcase	Kittanning, PA
17–20 Oct	8th ARO Workshop on Aeroelasticity of Rotorcraft Systems	University Park, PA
17–20 Oct	Penn State/ARO Workshop on Aeroelasticity of Rotorcraft Systems	State College, PA
19–21 Oct	RAC Design, Mechanical, Growth, Reliability, and Repairable System Analysis	Denver, CO
24–27 Oct	AGMA Gear Expo ’99	Nashville, TN
25–27 Oct	NDIA TACOM Advanced Planning Briefing for Industry	Dearborn, MI
26–18 Oct	AHS Rotorcraft Propulsion Specialist’s Meeting	Williamsburg, VA
Nov (TBA)	ARL Materials and Manufacturing Advisory Board Meeting	State College, PA
15–18 Nov	NDIA 3rd Annual DoD Maintenance Symposium	St Louis, MO
29 Nov–2 Dec	Defense Manufacturing Conference ’99	Miami, FL
6–9 Dec	NDIA 4th Annual Joint Services Hazardous Waste Management Conference	San Antonio, TX
27-30 Mar 2000	U.S. Army Ground Vehicle Survivability Symposium	Monterey, CA
2–4 May 2000	AHS Forum 56	Virginia Beach, VA
18–20 Apr 2000	Navy League Expo	Washington, D.C.
17–19 May 2000	JDMTP Sustainment Working Group	State College, PA



Quotable

“The rapid pace of civilian technology is limited to a few critical areas. It is not universal. The private sector does not run wind tunnels. There is no market for torpedoes. People who say we should rely on the public sector are, I think, distorting the real fact of the matter. We still have to make very heavy investment into the development of knowledge that has foreseeable military application.”

—Hans Mark, Director of Defense Research and Engineering

PENNSTATE

1855

Applied Research Laboratory
P.O. Box 30
State College, PA 16804–0030

Nonprofit Org.
U.S. Postage
PAID
University Park, PA
Permit No. 1

ADDRESS CORRECTION REQUESTED